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Electric shock hazard limitation in water during lightning strike

***Abstract**: Swimming during a thunderstorm is one of the most dangerous things that can be done. Lightning regularly strikes water, and since water conducts electricity, a nearby lightning strike could kill or injure human being. This paper will present simulation results of scalar potential distribution in water during lightning strike with respect to water conductivity. Lightning limitation buoy will be used for electric shock hazard reduction. All calculations results were obtained by CDEGS software.*

Streszczenie.** Kąpiel na otwartych akwenach w trakcie burzy jest jedną z najbardziej ryzykownych czynności, która może być wykonywana. Występujące wyładowania piorunowe w powierzchnie wody mogą spowodować obrażenia a nawet śmierć osób w niej się znajdujących. W tym artykule zaprezentowano wyniki obliczeń rozkładu potencjału w wodzie podczas bezpośredniego wyładowania piorunowego w wodę, w zależności od jej rezystywności. Zaproponowano wykorzystanie „boi piorunowej" dzięki, której uzyskano znaczące zmniejszenie zagrożenia porażenia prądem elektrycznym. **(Minimalizacja zagrożenia porażeniem prądem elektrycznym w wodzie podczas wyładowań piorunowych).

Keywords: lightning, swimming, water, electric shock hazard, lightning buoy.
Słowa kluczowe: wyładowanie piorunowe, kąpiel, woda, porażenie prądem elektrycznym, boja piorunowa.

Introduction

Swimmers sometimes get struck by lightning. For example in 2005 three people were struck while swimming in the ocean near Tampa, and four more were hit in waters off Chiba Prefecture, Japan. Two of them were seriously injured [1]. Swimming pools aren't necessarily safer too. In July 2006 a 50-year-old men was dangling his feet in the pool at a rented villa in Italy when lightning struck the water, killing him and injuring a friend [1]. Even showers and tubs are dangerous during thunderstorm because current can be transferred through plumbing.

Looking at US government data collected between 1959 and 2005, we see that incidents involving boats and water account for 13 percent of all lightning fatalities nationwide (among cases where circumstances are known), coming in behind instances where victims were out in the open (28 percent) or under a tree (17 percent). In Florida, which ranks first among the states in lightning casualties, boating and other water-related incidents make up 25 percent of lightning deaths [1, 2].

The chances that someone is going to be struck by lightning while swimming are strictly correlated with it height above water level. A lightning strike certainly can cause a high surge current to pass through water. The lightning current may spread out in all directions and dissipate within few meters or so. It is crucial to minimize this distance. Electric shock hazard bet on how close the strike will be. Distance of influence depends also on water type – salt or fresh [1].

This paper will present simulation results of scalar potential distribution in water during lightning strike with respect to water conductivity. Lightning limitation buoy will be used for electric shock hazard reduction. All calculations results were obtained by CDEGS software.

Water conductivity

Electrical resistivity is a measure of how strongly a material opposes the flow of electric current [3]. Electrical conductivity is the reciprocal quantity, and measures a material's ability to conduct an electric current [3]. When we describe water propriety conductivity is used instead of resistivity. During the lightning strike conductivity of water is major factor which corresponds to water potential rise.

The conductivity of a solution of water is highly dependent on its concentration of dissolved salts, and other chemical species that ionize in the solution. Electrical conductivity of water samples is used as an indicator of how salt-free, ion-free, or impurity-free the sample is [3]. The purer the water corresponds to the lower the conductivity. Conductivity measurements in water are often reported as specific conductance, relative to the conductivity of pure water at 25 °C [3]. Table 1 presents water conductivity for different type of it.

Table 1. Water resistivity and conductivity at 25 °C [3, 4]

Type of water	Resistivity [Ω·cm]	Conductivity [μS/cm]
Pure water	20000000	0,05
Distilled water	500000	2
Rain water	20000	50
Tap water	1000-5000	200-1000
River water (typical)	2500	400
River water (brackish)	200	5000
Sea-water (coastal)	30	33000
Sea-water (open sea)	20-25	40000-50000

Watering place model

This paper will consider electric shock hazard during lightning strike to water. Calculations were made for two different configurations. First one is typical case when swimmer is in the water alone. Second case is when swimmer is nearby "grounded" buoy. "Grounded" buoy is authors proposition to reduce lightning current influence on electric field in water. Scalar potential level is assumed as electric shock factor. Buoy were connected to 2m long copper wire with steel truss (1x1m) on it end. Proposed buoy could be a some kind of lightning protection system. It also protect against direct lightning strike to swimmer.

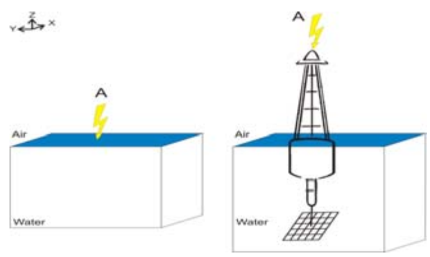

Fig. 1. Arrangement of watering place without and with grounded buoy

All calculations were performed for all described in table 1 river water types. It was assumed that water have got constant resistivity with respect to its depth. On figure 1 letter A reflect to assumed lightning strike point.

Numerical simulations were performed by MultiFields software package, which is a part of CDEGS package [5].

The numerical model includes an lightning channel (22m long), simple human body model (simple conductor with constant resistance equal 1kΩ) as well as simplified models of aboveground elements such as metallic buoy structure and simple steel truss on it end.

The computation methodology assumes frequency decomposition of the time domain current surge [5], frequency domain computations for a single harmonic unit current energization and superposition of the frequency domain computations modulated by the amplitude of the lightning current – shape 10/350µs, peak value 100kA [5].

(1) $$i(t)=\frac{I}{\eta}\left(e^{-\alpha t}-e^{-\beta t}\right)$$

where:t - time, a - reciprocal of time constant, b - reciprocal of time constant, I - peak current, η - correcting factor

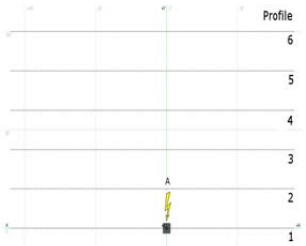

Fig. 2. Arrangement of the observation points

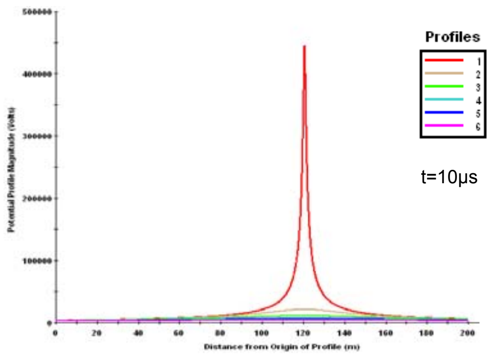

Fig. 3. Scalar potential distribution for river water without buoy

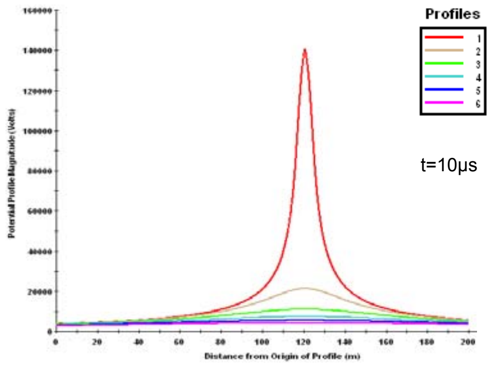

Fig. 4. Scalar potential distribution for river water with buoy

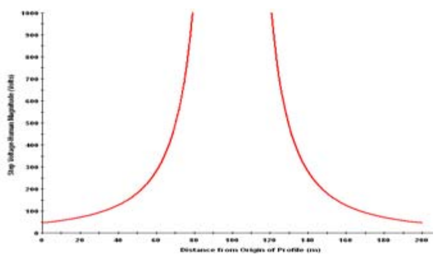

Fig. 5. Step voltage distribution for river water with buoy

Computation results

Calculations were made for six different profiles. Distance between them were equal 20 meters. Figure 2 presents arrangement of the observations points. Calculated scalar potential were along X-Y axis on constant depth equal 10cm (average distance from human neck to heart level). Figure 3 and 4 presents scalar potential distribution along for two cases - without and with lightning protection buoy. All presented results were for one selected moment in time - t=10µs. In this specific time scalar potential reaches its maximal value. Without buoy voltage magnitude reaches up to 440kV. With lightning protection buoy voltage rise up to 146kV. It is three times lower scalar potential value with respect to case without it. According to calculation results safe distance for a human being from lightning strike point is about 30 meters (see figure 5). As a safe voltage level 985V were assumed according the IEEE Std 80-2002 (fault clearing time 0,1s and step voltage 985 V) [6,7,8,9].

Conclusion

In order to ensure the safety of people at a open area such a watering place during the lightning, it is necessary to ensure protection against fulguration. Statistical data shows that direct lighting strike causes majority deadly accidents. Many accidents happen when storm and rain don't even started. The simulations allowed an evaluation of surface potential in open water area giving information about magnitude of crest value of scalar potential and the graphical distribution of it during lighting strike.

Proposed lighting protection buoy reduces probability of direct lightning strike. It also reduces scalar voltage level tree times. It is no difference in author opinion if buoy reach ground or not. The most important is scalar potential shaping and reduction hazard level nearby a water surface. Range of protection against direct lightning strike depends strictly to buoy height.

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